2009 Project Summary:

IMPACT OF DIKE STRUCTURES ON SEDIMENT TRANSPORT IN THE ALLUVIAL RIVERS

Proposal Number 52326EV

Guohong (Jennifer) Duan
Department of Civil Engineering
The University of Arizona

Objectives

The project has two components: one is to apply a computational model (EnSed2D) into a practical river engineering project in the Mississippi River, and the other is to collect laboratory experimental data for model verification, and to perform risk and uncertainty analysis of modeling results to explore uncertain parameters affecting the predictions. In particular, this project aims to conduct laboratory experiments of flow hydrodynamic and sediment transport around dikes. Flow and sediment transport field around the dikes of various alignments (e.g. angled, perpendicular, submerged, or emerged) will be measured in a series of experiments. These measured data will be used to verify the numerical model, and examine how dike structures of various alignments affect or improve water environments for in-stream habitat.

Approach

The proposed project consists of three parts: 1) conducting laboratory experiments to develop data for model verifications; 2) applying the EnSed2D model to the field site for evaluating the effectiveness of various design alternatives; 3) performing risk and uncertainty analysis of the modeling results to support management decisions. The objective is to study turbulent flow and sediment transport near dike structures of various geometries through an integrated laboratory experimental, numerical modeling, and field application. The result will be a feasible design of dike structures that can effectively reduce sediment deposition and maintain a favorable flow condition during winter low flows in the island. The risk and uncertainty of the selected design will be analyzed using the Monte Carlo simulation.

Significance and Army Value

The proposed research is significant: (1) using a practical engineering project as the objective to formulate research plans; (2) linking numerical models with laboratory experiments to enhance model's capabilities; (3) conducting risk and uncertainty analysis of numerical models for better decision making; and (3) increasing the visibility of women and minorities in engineering and sciences through educating and training women graduate and undergraduate students from the University of Arizona.

On a broader scale, this project demonstrated that the research product from an ARO funded project is a cost-effective tool for analyzing engineering alternatives for river management. The expected experimental and modeling results should provide useful insight into the management of flow and sediment in the Mississippi River, which is vital to preserve the integrity of ecosystem (Fig.1). In addition, the proposed study will provide valuable continuity with research previously funded by the Army Research Office

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Impact of Dike Structures on Sediment Transport in the Alluvial Rivers	**W911NF-07-1-0412**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The University of Arizona,Department of Civil Engineering,Tucson,AZ,85722-3308**	8. PERFORMING ORGANIZATION REPORT NUMBER **; 52326-EV.1**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army Research Office, P.O. Box 12211, Research Triangle Park, NC, 27709-2211**	10. SPONSOR/MONITOR'S ACRONYM(S) **ARO**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **52326-EV.1**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

to enhance sediment transport modeling in order to predict morphodynamic processes. The dataset will be disseminated through publications and the ASCE Task Committee on Computational Modeling of Sediment Transport Processes, where Dr. Duan serves as the committee chair of this committee.

Accomplishments

1. Conducted a series of experiments on flow field around several dike structures. Three model dikes were aligned perpendicular to the side wall in the experimental flume. Their lengths and spacing are scaled from the prototype dikes in the Mississippi River. Flow fields around the dikes were measured at various discharges by using a micro-acoustic Doppler velocity meter (Fig.2).

2. Upon the formation of scour hole, the horizontal flow separation zone behind the dike was shortened. The mean streamwise velocity has been reduced, but both the lateral and vertical mean velocities were increased. At sections upstream from the dike, the streamwise mean velocity has been reduced. In the meantime the turbulent intensity near the bed has increased so much that the Reynolds stress $-\rho\overline{u'w'}$ near the bed is less important than the corresponding turbulent intensity. At the dike section, the transverse mean velocity $\bar{v}$ was increased considerably and the u' and v' has enhanced so significantly that the Reynolds stress $-\rho\overline{v'w'}$ is less important than the corresponding turbulent intensity at the dike tip. Downstream from the dike in the primary flow zone, turbulent intensity u' has increased more than that of v'. But the increase in w' primarily resides in the recirculation zone. Reynolds stress $-\rho\overline{u'w'}$ near the bed at the primary flow zone is less important than the corresponding turbulent intensity.

3. Quadrant analysis of experimental data sets indicated that, the lifting of sediment particles in the scour hole was caused by the sweep and ejections ($u'>0, w'<0$; $u'<0, w'>0$), and the rolling of sediment particles was driven by the sweeps and outward interactions by u' and v'. In contrast, before the local scour was initiated, the magnitude of w' was much larger than those measured after the scouring hole has fully developed, but u' and v' had increased at the scoured bed surface.

Technology Transfer

- Provided recommendations to the Corps of Engineers, Rock Island District on the flood defense system in the Iowa river. We suggested the Corps to construct gates on levees to divert floods that exceed the levee's capacity. Our method requires an integrated flood defense system that includes levee, detention basin, and flood gates. These well designed gates can increase flood capacity without elevating the levees.

- We invited Dr. Jack Davis, Technical Director at Engineering Research and Development Center at Vicksburg, Mississippi, visited Univ. of Arizona in 2007. Since then, the PI have discussed with Dr. Davis and Dr. Hubbard and others in ERDC regarding this project and the applications to navigation system in the upper Mississippi River.

Publications

One paper has been accepted, and two papers are under review currently. Two abstracts were presented at 2009 AGU Fall conference. One graduates student, Mary Yaeger, is expected to graduate in May 2009.

Duan, J. G., Acharya, A. and Yaeger, M. (2008) Turbulent bursts and sediment sorting around experimental spur dikes, *Proceedings of ASCE World Environmental Resources Congress, Honolulu, USA.*

Duan, J. G. Mean flow and turbulence around a spur dike, Journal of Hydral. Engrg., in press.

Duan, J. G. and He, L., Turbulent burst around an experimental spur dike, Journal of Hydraul. Engrg., in review.

Duan, J. G. and He, L., Mean flow and turbulence in a scoured hole around an experimental spur dike, Advance in Water Res., in revision.

Awards/Honors Received in 2008-2009

- NSF Career Award – this award is the most prestigious NSF award to junior faculty.
- Diplomate, American Academy of Water Resource Engineers —The PI was recognized as diplomate of American Academy of Water Resource Engineers. The membership is given to senior water resource engineers to recognize their accomplishments.
- Arizona Floodplain Management Scholarship—One graduate student (Mary Yeager) working on the project received the Arizona Floodplain Management Scholarship ($2000), which is to award outstanding graduate students in the area of water resource and floodplain management.

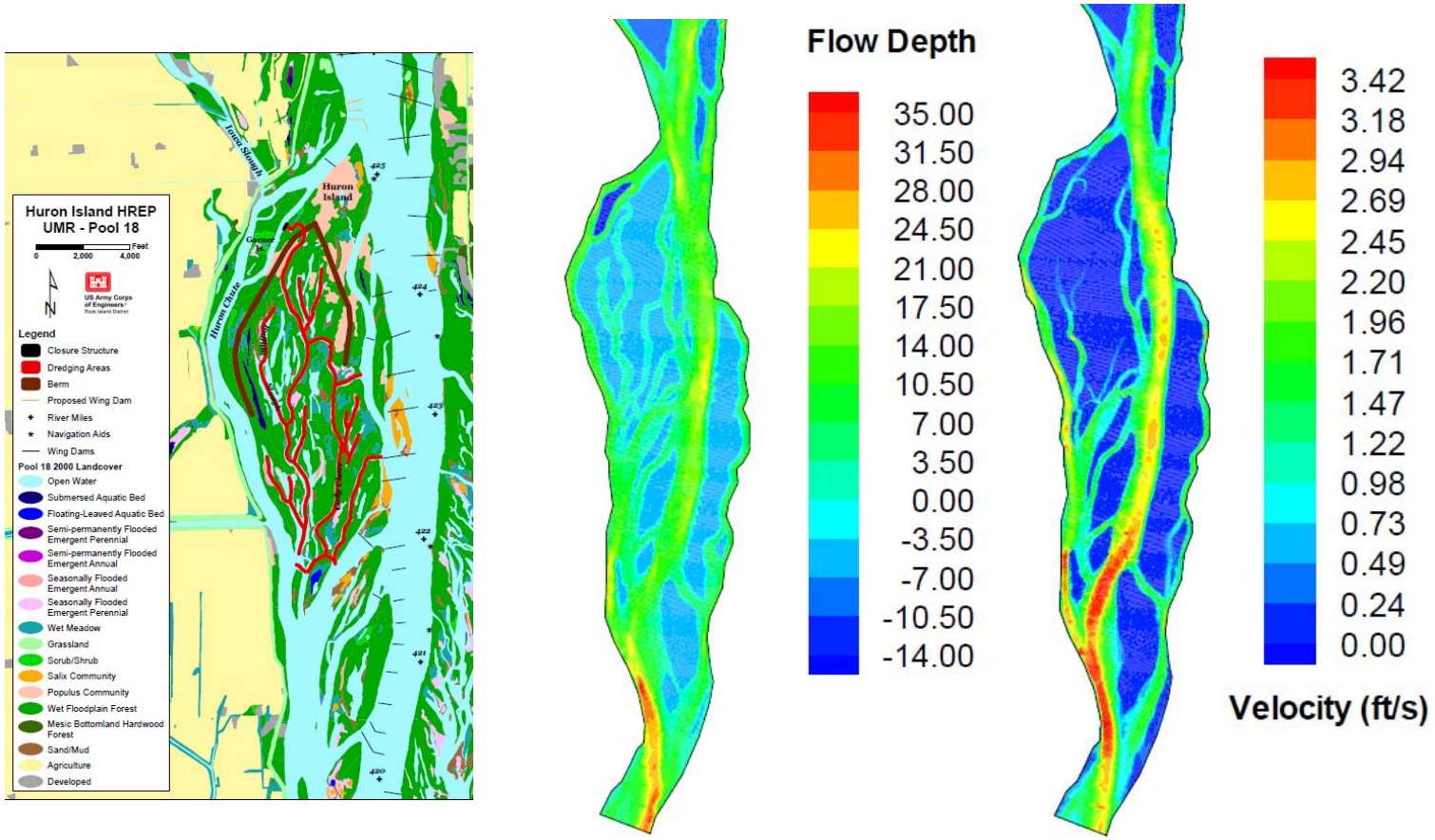


Fig.1. Simulated flow depth comparing to the results of field survey

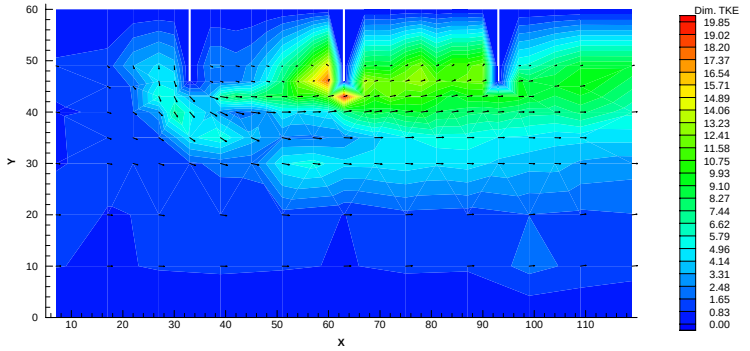
Note: The minimum flow depth for the native fish in the Huron Island is 4.0 ft. This figure showed that more than 50% waterways in the island will not have enough flow depth for native fish during the winter time. The loss of quality habitat is a result of excessive sedimentation in the pool. The corresponding velocity distribution showed the locations of dead waters having poor water quality. This result proves the applicability of 2D model in analyzing the complex river network for ecosystem evaluation.

Dikes in Mississippi River

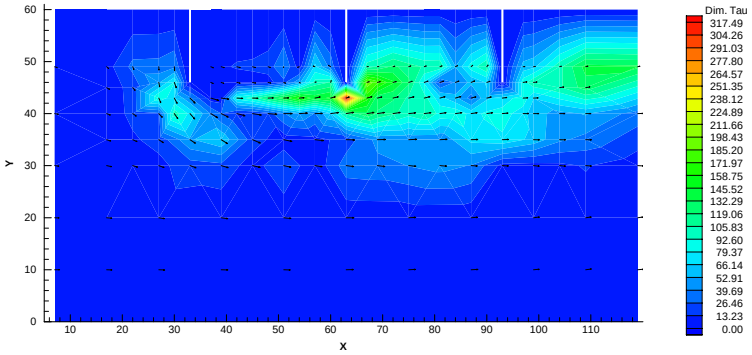
Experimental Dikes

Fig.2. Experiments of turbulent flow field near dikes

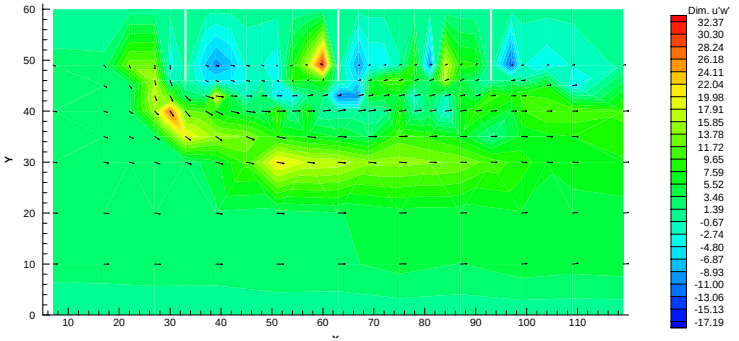
Note: This figure showed the experimental results of turbulent flow field near dikes. Since there is no perfect answer regarding how sediment was entrained and transported, we measured detailed flow field near bed. The results showed that both the maximum shear stress and kinetic energy occurred at the second dike, the most venerable one for erosion. The distribution of Reynolds stress is different from that of turbulent kinetic energy and requires further investigations. The next step is to study sediment transport under these turbulent structures.



Dimensionless Kinetic Energy



Dimensionless Shear Stress



Dimensionless Reynolds Stress